IN THE SPECIFICATION

Please add the paragraphs as indicated by the following:

On pages 2 and 3, rewrite the entire section DESCRIPTION OF THE RELATED ART: as follows:

Generally, electronic devices are provided with a large number of heat-generating components and modules. As a result, in order to prevent the interior of the device from overheating, a cooling system has to be introduced. In recent years a cooling system for efficiently cooling the individual printed circuit boards that carry high heat dissipating electronic semi-conductor components or the semi-conductor components or modules mounted o the conductive surface of a cold plate. Conventionally, the cooling systems used in electronic devices are of two types: forced-air types and forced –liquid types. FIG 1A is a diagram showing a conventional forced-air type cooling system 500, [Gig.] <u>FIG</u> 1B is a diagram showing a conventional forced-liquid type cooling system 600.

As shown in FIG 1A, the air-cooled cooling system 500 has a heat sink 503 made from conductive material having a high rate of heat transmission such as aluminum or copper is provided on a heated part 501. The heat sink 503 is provided with a multiplicity of fins in order to increase the radiative effect. In the cooling system 500 a flow of air forcibly created by a fan 505 cools these fins and so cool the heated part 501.

Additionally, as shown in FIG.1B, the liquid-cooled cooling system 600 has thermally conductive cold plates 603 provided in direct contact with the heated part 601. These cold plates 603 are positioned so as to contact a pipe 604 through which a liquid coolant 609 circulates opposite the heated part 601. When the liquid coolant 609 passes through the

heat exchanger 607 it is heat exchanged and cooled, so the cold plats 603 can also be cooled and, accordingly, the heated part 601 is also cooled. This liquid-cooled cooling system 600 has a pump 605 and a heat exchanger 607 having a fan 608 to forcibly cool the heated part 601.

However, the above-described air-cooled cooling system 500 uses air to cool the heated member 501, so the rate of heat transmission is very low and the radiative effect is poor[.].

The liquid-cooled cooling system 600 described above, although it has good thermal conductivity, nevertheless still uses a pump 605 and a fan 608 and so is subject to the same disadvantages as those pertaining to the air-cooling system 500 described above, namely heat transmission is relatively low and radiative effect is poor.

The prior art teaches the use [the ] of heat dissipation devices in forming cooling systems for cooling electrical and electronic semi-conductor devices and modules, but does not teach such systems having the features of high performance, low cost, low specific weight, specific volume per unit power dissipation cooled and ease of manufacture. The present invention fulfills these needs and provides further related advantages as described in the following summary.

On page 5, before the paragraph beginning "FIG. 2", insert:

FIG. 1A is a cross-sectional view of a prior art forced-air type cooling system;

FIG. 1B is a cross-sectional view of a prior art liquid type cooling system;

On page 5, before DETAILED DESCRIPTION OF THE INVENTION, insert:

FIG. 5 is a top plan view of a cold plate assembly according to the invention;

FIG. 6 is an enlarged cross-sectional view of the cold plate assembly attached to a printed circuit board shown taken along line 2-2 of FIG. 5;

FIG. 7 is a top plan view of a cold plate assembly using individual heat pipes;

FIG. 8 is an enlarged cross-sectional view of a cold plate assembly attached to a printed circuit board shown taken along line 4-4 of FIG. 7;

FIG. 9 is a cross-sectional view of a cold plate assembly using individual heat pipes attached to a printed circuit board shown taken along line 5-5 of FIG. 7; and

FIG. 10 is a block diagram illustrating steps employed according to one embodiment of the method of the present invention.

On page 7, before the paragraph beginning on line 24, insert:

A conductive cold plate 25 of the present invention employs an easily manufactured modular construction made of three modules or elements. The three modules including a thermally conductive base 2, a heat pipe assembly 20, and compact heat exchanger 14 are described below.

A thermally conductive base 2 comprises a rectangular shaped plate of thermally conductive material, and provides a circuit board engagement interface. The interface is formed with a series of recesses that mirror the surface component topology of a circuit board 1, and a standoff 10 for mounting the cold plate 25 to the board 1. This thermally conductive base 2 is preferably made from machined aluminum alloy 6061 T6. In case of mass production to further reduce the cost of this module, die case aluminum alloy, brass or high conductivity polymer composite can be used.

A heat pipe assembly 20 is preferably constructed as a thermal plane utilizing embedded copper/water heat pipes 9 & 11 sandwiched between two outer aluminum

plates. The heat pipes thermal plane utilizes embedded heat pipes to carry the heat from components (the heat source) to the heat sink (heat exchangers) with a typical source to sink temperature difference of 20 degrees centigrade or less. While cooling at both edges is recommended for maximum heat pipe thermal plane performance, single edge cooling is possible with lower performance. Operation is sensitive to orientation of the heat pipes 9, shown in FIG. 7 and FIG. 8. A heat pipe 9 is a heat transfer device with an extremely high effective thermal conductivity. Heat pipes are evacuated vessels typically circular in cross section which are back filled with a quantity of a working fluid and they are totally passive as used to transfer heat from a source (electronic components) to a sink (heat exchangers) with minimal temperature gradient or to isothermalize a surface. Common heat pipe types used are wicked, pulsating or loop heat pipes. Common heat pipe fluids used are ammonia, water, acetone, and methanol. The heat pipe thermal plane 20, shown in FIG. 5, and heat pipes 9 shown in FIG. 7 are selected depending on the cooling system parameters to carry the heat from the electronic components through the base 2 to the cooling fluid in the heat exchanger 14. When using two compact heat exchangers at the edges of the cold plate base 2, cold plate performance is maximized due to maximum performance of heat pipe thermal plane. Single edge cooling using one heat exchanger is possible with slight de-rated performance. The efficiency of the cold plate 25 is dependent on mounting orientation as noted previously.

With reference to the figures, preferably a heat exchanger 2 and 14 is disposed at one or both opposite ends of heat pipe assembly 20. Preferably, the one or two heat exchangers are either laminated or finned. Moreover, preferably the heat exchanger is

made of aluminum or copper and sized to accommodate the heat dissipation capacity of the printed circuit board. The flow rate of flow of the cooling fluid required is determined in proportion to the heat removal capacity of the cold plate 25, and a junction temperature range is maintained for the cooled electronic components mounted on the printed circuit board. With reference to FIG. 5, where two heat exchangers are provided, preferably, both are connected together with two aluminum or copper pipes 15 and 16 to transmit the cooling fluid. The pipes are connected to the inlet and outlet of the heat exchangers. The path of the cooling fluid is from an inlet quick disconnect 4 to the lower heat exchanger 3, then to pipe 15 and through the upper heat exchanger 14 to the pipe 16, and finally, out through the quick disconnect 5.

Referring to FIG. 6 the three module cold plate base 2, heat pipe thermal plane 20, and heat exchangers 3 and 14 are assembled together using high thermal conductive adhesives or any other thermally conductive bonding technique on the cold plate base outer surface. A template or fixture (not shown) is used to accurately locate the three modules in place relative to the controlling dimensions in the assembly process of the cold plate 25. The circuit board 1, with electronic component item 13, to be cooled is mounted on printed circuit board 1, and gap filler 35 is placed between the circuit board 1 and base plate 2. The circuit boards cooled by the cold plate in this invention are not limited in size, since heat pipe thermal or individual heat pipes can be custom designed to accommodate the cold plate size to cool the circuit board electronic components. Also the heat transmission capacity of the heat pipe thermal plane 20 can be customized to maximize the capacity and performance by changing the length, width and thickness of the heat pipe thermal plane 20. With reference to FIG. 7, the working

fluid in the heat pipe thermal plane 20 can be of different types and, similarly the individual heat pipes 9, can be of different sizes (diameter, length, etc.) to accommodate the cooling capacity and the dimensions of the assembly. In the industry there are standard sizes of the heat pipe thermal plane 20 predesigned and available for production orders. In the case of using a heat pipe thermal plane, the use of the standard size of the heat pipe thermal plane reduces the cost of this module in the cold plate of this invention over the use of customized heat pipe thermal planes.

Referring now to FIGS. 7-9, the cold plate 25 of the present invention, generally employs a highly manufacturable modular construction, including a thermally conductive base, individual heat pipes, and plural heat exchangers. The cold plate 25 includes a rectangular shaped base plate of thermally conductive material such as aluminum, brass or high conductive polymer composite, having a circuit board engagement interface. The interface is formed with a series of recesses that mirror the surface component topology of the circuit board, with thermally conductive gap filler material (not shown). Reference numeral 3 refers to a laminate or finned heat exchanger. Reference numerals 4 and 5 refer to quick disconnects for the cooling fluid entering and exiting the heat exchanger. Reference numeral 7 refers to an electronic component to be cooled. Reference numeral 9 refers to the heat pipes. Reference numeral 2 refers to a thermally conductive base. Reference numeral 12 refers to a gap filler material. Reference numeral 10 refers to an alignment pin.

With reference to FIGS. 7-9, in an additional embodiment of the present invention, the three modules of the cold plate assembly are a cold plate base 2, individual heat pipes defining a heat pipe assembly 20, and one or more heat

exchangers 3. The three modules are assembled together using brazing material like thermally conductive adhesive or soldering material or any other thermally conductive bonding technique. The individual heat pipes are bonded to the thermally conductive base's outer surface, by providing cavities to house the individual heat pipes. The heat exchanger 3 then is bonded to the cold plate base 2 using thermally conductive bonding material. A template or fixture is used to accurately locate the three modules in place relative to the controlling dimensions in the assembly process of the cold plate.

Referring now to FIG. 10, the structure of the cold plate assembly 25 enables the implantation of relatively straightforward assembly steps. Manufacturing the cold plate begins in step 100, with selecting a thermally conductive plate to define the base. Either casting or machining the profile of the topology on the far side forms the base. Then selecting the heat pipe thermal plane or individual heat pipes at step 102. Selecting the compact heat exchanger with the pipes in step 104.

Once the three main modules are selected, bonding them together as shown in FIGS. 5-9 makes the assembly of the cold plate step 106. Using a thin layer of high thermal conductive adhesive makes the bond. While the inventor has determine bonding using high thermally conductive adhesive offers the preferred results, other known processes may be employed without damaging the heat pipe thermal plane or the individual heat pipes.

Assembling the cold plate includes the base, the heat pipe thermal plane or individual heat pipes and the heat exchangers. The thermal capacity of transmitting the heat as determined by the main parameters of the heat pipe thermal plane or individual heat pipes. For a properly designed heat pipe thermal plane or individual heat pipes,

depending on parameters, capacity for transmitting heat energy can handle applications with peak thermal flux range of more than 80 watts/square centimeter at the interface. Effective the thermal conductivity of the heat pipe thermal plane or individual heat pipes can virtually range over several multiples the effective thermal conductivity of copper depending on the parameters of the heat pipes used. The compact heat exchanger capacity for removing the heat to the cooling fluid is determined by the selected heat exchangers capacity. This defines the temperature level and the cooling capacity of the cold plate.

The cooling of high-power printed circuit boards is accomplished in this invention with cold plates mounted with the engagement interface positioned directly on the electronic component surface. Thermal putty interface material gap filler applied at the circuit board-to-cold plate interface junction ensures diminished air gaps to maximize the cooling effect of the cold plate.